LATE CRETACEOUS SELACHIANS FROM INDIA AND THE AGE OF THE DECCAN TRAPS

by G. V. R. PRASAD *and* H. CAPPETTA

ABSTRACT. Thin sedimentary sequences associated with the Deccan Traps (infra- and intertrappean) of peninsular India have previously been dated as ranging in age from Late Cretaceous to Early Oligocene. Systematic work carried out in recent years on the fauna and flora of these sedimentary beds has led to the discovery of many previously unknown microvertebrate, invertebrate, and plant remains. The present paper deals with the systematics and stratigraphical significance of batoid fish remains from Asifabad and Marepalli, Andhra Pradesh state, India. The selachian fauna of these localities, represented by isolated teeth and dermal denticles, is identified with the genera *Raja*, *Rhombodus*, and *Igdabatis*. All the dental remains referred in earlier works to *Dasyatis* and *Rhinoptera* are now identified as lateral teeth of *Igdabatis*. The study reveals the presence of two new species: *Raja sudhakari* sp. nov. and *Igdabatis indicus* sp. nov. obtained from the infratrappean and intertrappean beds of Marepalli and Asifabad respectively. The new palaeontological data support a Late Cretaceous, Maastrichtian, age for the infra- and intertrappean beds of peninsular India.

THE volcanic rocks of peninsular India popularly known as 'Deccan Traps' cover over one third of the total area and have been a topic of discussion at many national and international symposia in the past. These rocks are interbedded at many places with fossiliferous sedimentary beds designated as 'infratrappean' (underlying the basal flow) and 'intertrappean' (enclosed between two flows). Over a period of more than a century, Deccan volcanic flows have been dated as ranging in between the Late Cretaceous and the Early Oligocene based on inconsistent K-Ar dates of the lava flows (Rama 1968; Kaneoka and Haramura 1973; Agarwal and Rama 1976; Alexander 1981) and biostratigraphically insignificant plant fossils and molluscs occurring within the intertrappean beds (Hislop 1860; Sahni 1934; Prakash 1960; Bhatia and Mannikeri 1976; Shivarudrappa 1978). In view of the longstanding disparities in the age determinations and the significance attached to Deccan Traps in some of the theoretical models to explain mass extinctions at the Cretaceous-Tertiary boundary, concerted efforts have been made to obtain a representative sample of infratrappean and intertrappean fauna and flora from widely separated localities in peninsular India.

The present paper is the result of a collaborative research project carried out by the Departments of Geology, Panjab and Jammu Universities, India and the Laboratoire de Paléontologie, Université des Sciences et Techniques du Languedoc, Montpellier, France in the last five years. As a consequence of this collective effort, a larger number of microvertebrate, invertebrate, and plant remains have been collected from the infratrappean as well as intertrappean sedimentary sequences.

The microvertebrate fauna comprises fish, anurans, lacertilians, snakes, turtles, crocodiles, dinosaurs, and mammals; the invertebrate fauna is composed of gastropods, bivalves, and ostracodes. Charophytes, pollen, and spores substantiate the floral component. A significant variation is, however, noticed in the biotic component at one of the investigated localities. The intertrappean beds of Naskal, occurring on the southeastern margin of Deccan Traps, yield predominantly freshwater and terrestrial elements whereas the infra- and intertrappean sequence of the eastern margin such as Jabalpur, Nagpur, Pisdura, and Asifabad produce a mixed assemblage of freshwater and marine elements. The selachian teeth described in this paper have been obtained from an infratrappean section exposed southwest of the village of Marepalli (lat. 17° 20′; long. 77° 42′), Rangareddi District and an intertrappean section located 2·5 km south of the village of

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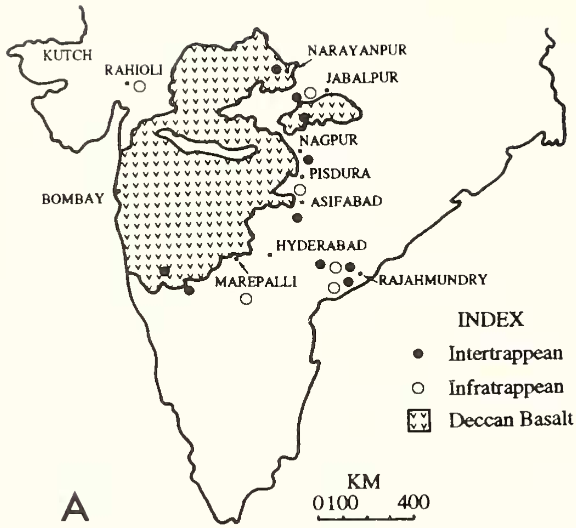
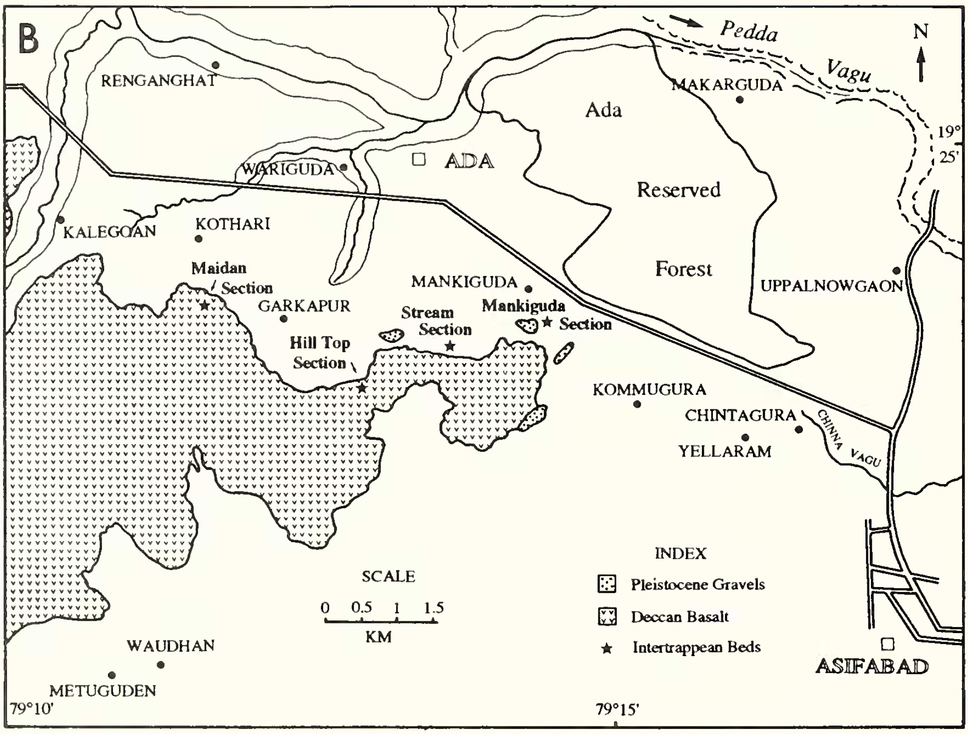
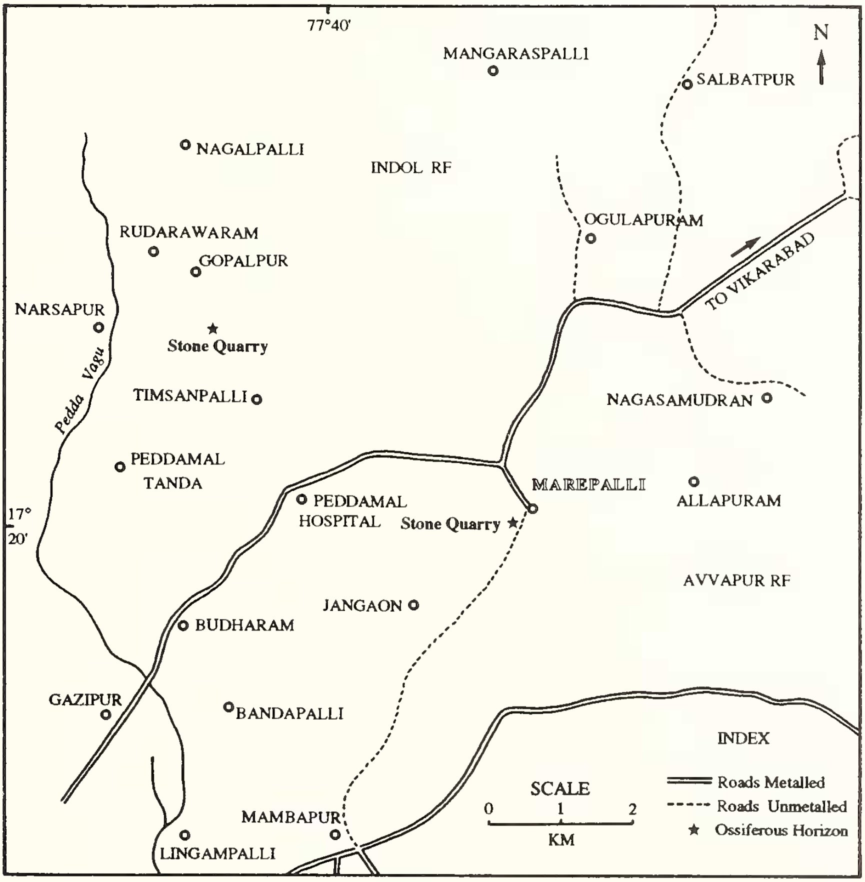




TEXT-FIG. 1. Location maps of the investigated localities. A, distribution of infra- and intertrappean beds in peninsular India. B, detailed locality map of Asifabad.

Ada (lat. 19° 25′; long. 79° 15′), Asifabad Taluq, Adilabad District, Andhra Pradesh (Text-fig. 1). The volcano-sedimentary sequence of Asifabad represents the eastern extension of the Deccan Traps in the Pranhita-Godavari Valley and is underlain by a succession of Precambrian and Gondwana Group rocks. Four intertrappean sections have been demarcated in this region out of which one, very close to the village of Ada and designated as 'stream section', proved to be rich in batoid fish remains (Text-fig. 2). The selachian teeth were recovered mainly from quartz arenite and lithic wacke units. Though a few lateral teeth of *Igdabatis* are known from the basal lithic arenite, it is the rajids which dominate the batoid component of this unit. Associated fauna and flora include freshwater fish, anurans, lacertilians, snakes, crocodiles, dinosaurs, molluscs, ostracodes, and charophytes. The infratrappean beds of Marepalli, on the other hand, constitute a part of the volcanic sequence on the southern margin of the main mass of Deccan Traps. The bone-bearing section is exposed in a quarry located southwest of the village of Marepalli. Here, mudstones of different hues yielded only the remains of fish, frogs, turtles, crocodiles, and dinosaurs and are devoid of invertebrate and plant remains (Text-fig. 2). The batoid collection of Marepalli includes dental remains of *Igdabatis* and *Rhombodus*, and a few dermal denticles. Dentition of *Raja* is not known from this locality and this seems to be characteristic of all infratrappean (Lameta) sequences such as Jabalpur and Pisdura.

Selachian fish are known to show considerable variation in their dental morphology, which is



TEXT-FIG. 2. Detailed locality map of Marepalli.

attributed to various factors such as their position on the jaw, maturity of the animal, and sexual dimorphism (Cappetta 1987). When complete dental plates of batoids are available, one can make the taxonomic assignment with greater confidence, but when there are only isolated teeth, such studies are susceptible to misinterpretations. In India, batoid fish of Cretaceous age have so far been recovered from the infratrappean beds of Jabalpur, Pisdura, and Marepalli, and the intertrappean beds of Nagpur and Asifabad. The Jabalpur collection includes a single broken median tooth and a few lateral teeth which have rightly been referred to the genus *Igdabatis* (Courtillot *et al.* 1986; Tripathi 1986). The fauna from Pisdura consists of a few median and lateral teeth (Jain and Sahni 1983), who compared the median teeth with *Igdabatis sigmodon* Cappetta, 1972 (but referred them to *I. sigmoides*; [*sic*, a misprint for *sigmodon*]). These authors also assigned the lateral teeth of *Igdabatis* affinity to *Rhinoptera*. The batoid collection from Nagpur includes only lateral teeth of *Igdabatis* but based on morphological differences, they were placed under different species of *Dasyatis* and *Rhinoptera* (Rana 1984). Similarly, the teeth from Asifabad have been related to various species of *Dasyatis*, *Rhinoptera*, *Rhombodus*, *Raja*, and *Igdabatis* (Prasad 1985; Prasad and Sahni 1987). In addition to the collections from the above-mentioned localities, a few lateral teeth referable to *Igdabatis* have recently been recovered from the intertrappean beds of Gurmatkal (Srinivasan, personal communication) and Naskal. Comparison of the Indian material with rich African selachian faunas, and dentition of many living forms available to one of us (H. C.) necessitated a revision of preexisting systematics of fossil selachians of India. All the lateral teeth which were earlier referred to different species of *Dasyatis* and *Rhinoptera* could now be compared by extrapolation to the lateral series of *Igdabatis*. It is further realized that the Indian teeth could not be assigned to any of the previously described species of *Raja*, *Rhombodus*, and *Igdabatis*. The terminology used in the description of the teeth follows Cappetta (1987). The specimens described in the present paper are stored in the Vertebrate Palaeontology Laboratory, University of Jammu, Jammu Tawi, India and referred to by their VPL/JU numbers.

SYSTEMATIC PALAEONTOLOGY

Superorder BATOMORPHII Cappetta, 1980
Order RAJIFORMES Berg, 1940
Suborder RAJOIDEI Garman, 1913
Family RAJIDAE Bonaparte, 1931
Genus RAJA Linnaeus, 1758

Type species. *Raja batis* Linnaeus, 1758, Recent.

Raja sudhakari sp. nov.

Plate 1, figs 1–7

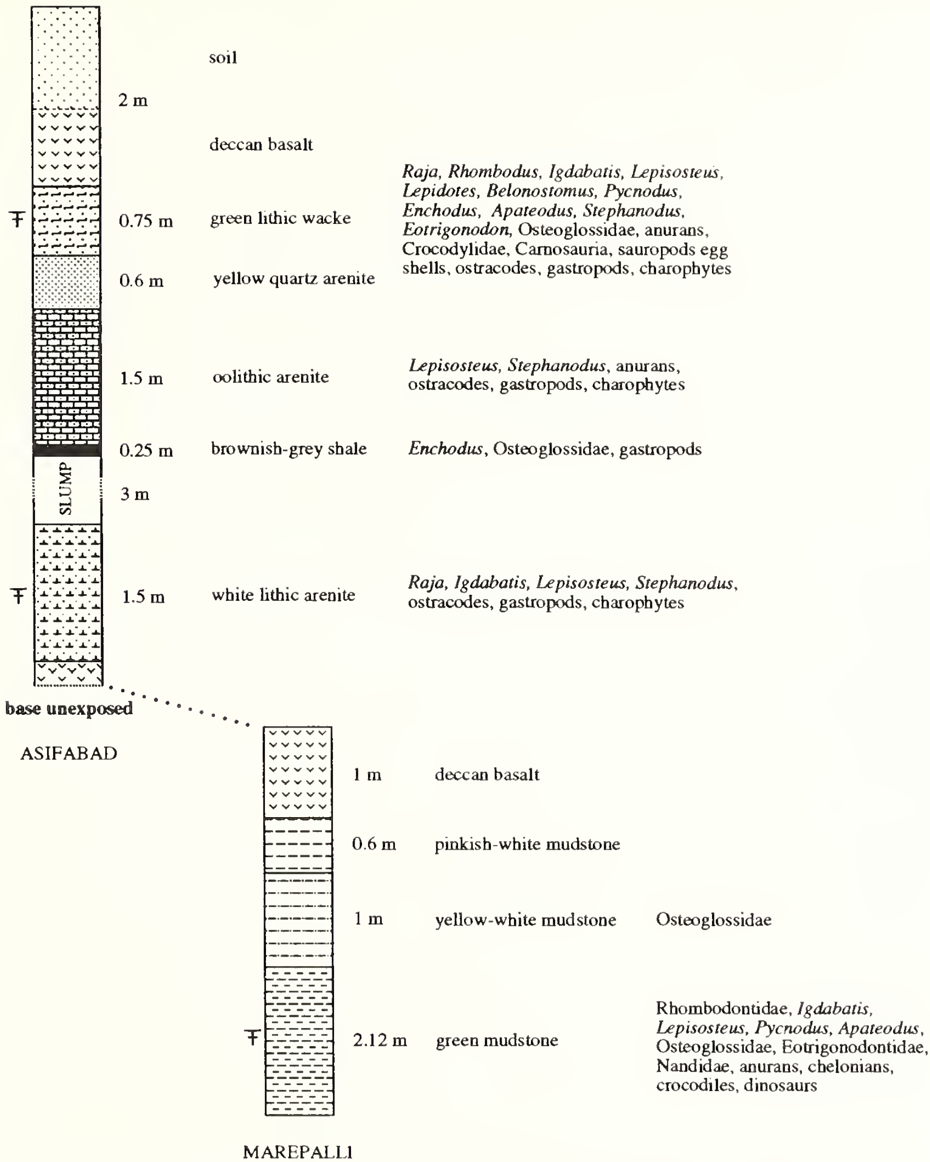
Material. Sixty-five isolated median and lateral teeth.

Horizon and locality. Intertrappean beds (green lithic wacke of Text-figure 3) of Asifabad, Andhra Pradesh, India.

Holotype. VPL/JU 101; Pl. 1, fig. 2*a–c*.

Derivation of name. The species is named in honour of Shri G. Sudhakar, Sarpanch (chief) of the village of Ada, Asifabad Taluq, Adilabad District, Andhra Pradesh, India for his generous and unfailing help during the field work.

Diagnosis. Teeth of small size (less than 1 mm width) with a crown longer than wide and showing a generally well-differentiated cusp. In occlusal view, the crown shows a rhombic outline, with a



TEXT-FIG. 3. Stratigraphical columns of the ossiferous sections.

lingual part more developed than the labial one. The marginal angles are distinct but not acute. There is a well marked medio-labial angle, often blunted and a distinct uvula partially overhanging the root groove. The cusp is high and bulky with a well-marked transverse keel joining the lateral angles. In profile view, the lingual outline of the cusp is almost vertical and the labial one oblique. The lower part of the visor is wide, gently rounded and oblique, well separated from the labial face of the crown by a distinct ridge.

Root much narrower than the crown in occlusal view, with labio-lingually elongated lobes separated by a deep groove; basal face of each lobe transversally convex and oblique in labial view; a large foramen opens in the labial part of the groove.

Description. Teeth with a rather low cusp in comparison to very long, elongated cusps found in recent and many fossil rajids. This is indicative of weak sexual dimorphism in the Indian species. The teeth, probably belonging to the parasymphyseal and anterior rows, have crowns with roughly rhombic outline with the long axis lying in the labio-lingual direction (Pl. 1, figs 2–3). The central part of the crown is projected into a conical cuspid which points lingually. In profile, the cuspid has nearly a vertical face on the lingual side with a slight concavity at the base and an inclined convex base on the labial face. The summit of the cuspid is connected to the lateral margins of the crown by transverse cutting ridges. The cuspid is more developed lingual to the transverse ridge. The labial and lingual margins of the crown are convex in outline but in a few teeth, the labial margin is truncated in its median part and exhibits a weakly concave outline (Pl. 1, fig. 1*a–b*). The crown margin all around the central cuspid is slightly raised with a shallow depression at the base of the cuspid. The median part of the crown on lingual margin is slightly bulged and in many teeth bears a central uvula. The crown is much higher than the root and almost completely covers the lingual face of the root. The labial face of the crown overhangs the root to such an extent that its length is nearly equal to the total length of the root. The teeth show various stages of wearing due to occlusion. In teeth with little wearing, only the summit of the cuspid is eroded (Pl. 1, fig. 6), while in teeth with maximum wearing, the cuspid is completely worn out to the base (Pl. 1, fig. 1). In some cases, even the basal crown is worn out to a flat surface. Many intermediate stages between the two extremes of wearing also exist. The root is very small (half the width of the crown or even less), inclined lingually, and is divided into two subtriangular or crescentic lobes labio-lingually elongated by a deep and wide groove.

Discussion. The lobes may or may not be equal in size and have generally convex basal faces. A foramen opens at the labial extremity of the root groove. No other foramina are visible on the lingual and labial faces of the root. Small teeth with reduced cuspids may belong to the females but they could also be compared to the lateral teeth of a male. As discussed earlier, the remarkable variation in the dentition of rajids does not allow a precise allocation of these teeth either to the females or males.

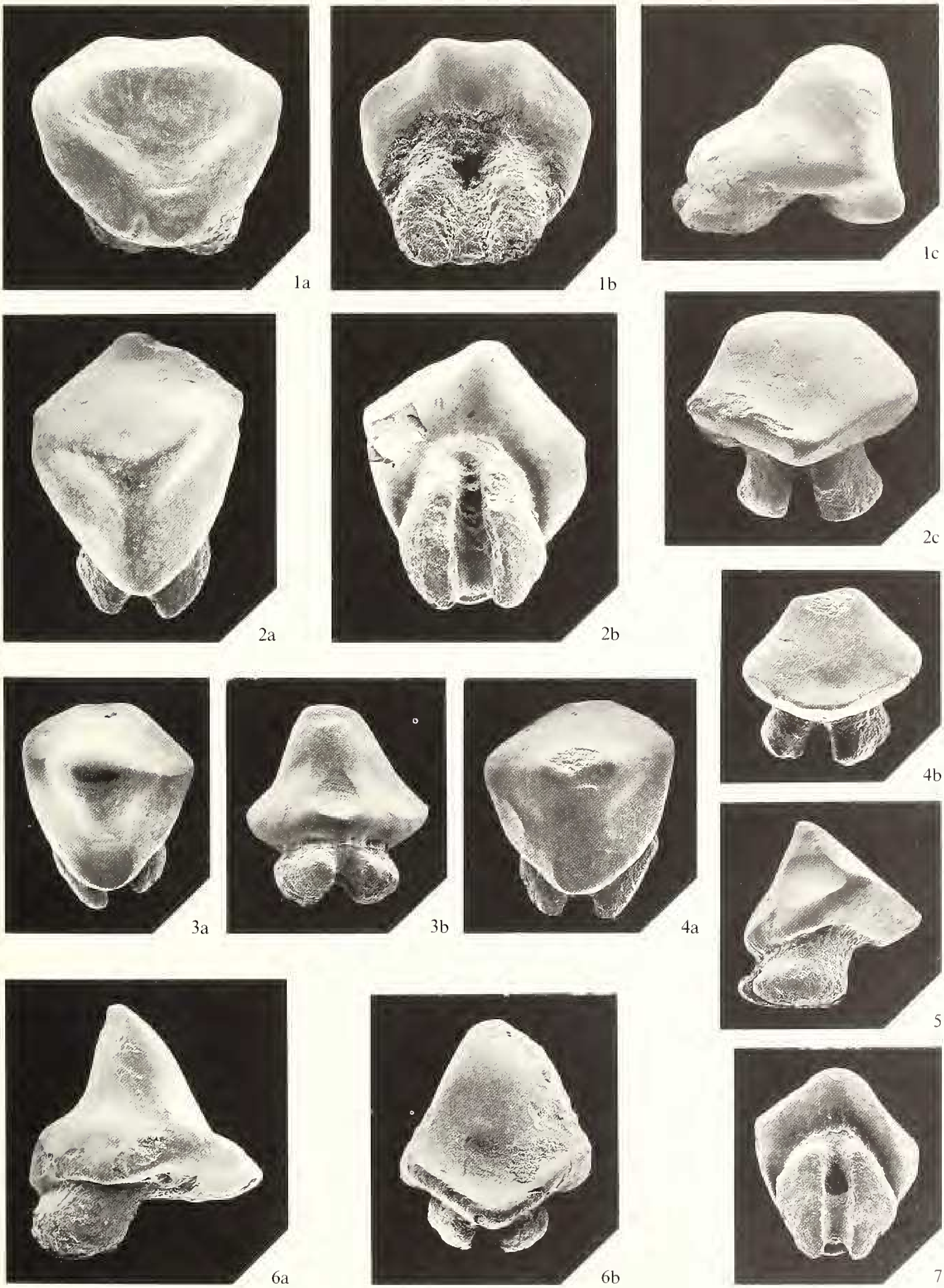
Ward (1984) suggested that the presence of a root directly below the crown may be considered as a diagnostic feature of females, but this rule does not apply to all species of *Raja*. If the present teeth are distinguished by the above criterion, then they should be identified with males as they have more lingually placed roots. The crown in these teeth is approaching an elliptical outline. In extreme lateral teeth, the cuspid is highly reduced and only in the form of a feeble transverse crest and the crown attains the elliptical outline. The labial face of the crown is flat and convex on the labial margin. There is a minor concavity on the lingual face below the transverse crest and the lingual margin of the crown is bulged. The root is inclined lingually but in some cases, it is nearly central in position. A wide and deep root canal divides the root into two crescentic and basally convex lobes.

The family Rajidae includes more than two hundred species distributed among about twenty subgenera or genera (McEachran and Miyake 1990). This family exhibits a broad range of dental morphological diversity according to the species; to the normal interspecific dental variations are added intraspecific variations which are often pronounced because of a very marked gynandric heterodonty. By their morphological features, the teeth of the Indian rajid can be assigned unequivocally to the genus *Raja*. The majority of the species of *Raja* are known from Tertiary deposits all over the world. Affinities of the only Cretaceous (Late Santonian) species *R. davisi* Fowler, 1958 are doubtful (Cappetta 1987). The Tertiary forms of *Raja* are represented by *R.*

EXPLANATION OF PLATE 1

Figs 1–7. *Raja sudhakari* sp. nov.; Maastrichtian, intertrappean beds of Asifabad. 1, VPL/JU 100; lateral tooth; *a*, occlusal view; *b*, basal view; *c*, profile. 2, VPL/UK 101, holotype, anterior tooth; *a*, occlusal view; *b*, basal view; *c*, labial view. 3, VPL/JU 102; anterior tooth; *a*, occlusal view; *b*, lingual view. 4, VPL/JU 103; anterior tooth; *a*, occlusal view; *b*, labial view. 5, VPL/JU 104; anterior tooth, profile. 6, VPL/JU 105; anterior tooth; *a*, profile; *b*, labial view. 7, VPL/JU 106; anterior tooth; basal view. All figures ×43.

PLATE 1



PRASAD and CAPPETTA, *Raja*

harrisae (Lower Eocene of England, Ward 1984), *R. gentili* (Middle Miocene of France, Joleaud 1912; Cappetta 1970, 1975; Lower and Middle Miocene of Switzerland, Leriche 1927), *R. casieri*, *R. cecilae*, *R. heinzelini*, *R. terhangensis* (Early Oligocene of Belgium, Steurbaut and Herman 1978) and *R. louisi* (Late Palaeocene of Niger, Cappetta 1972). Comparison of the Indian specimens with these forms leads to the following observations. *R. sudhakari* differs from *R. louisi* in which the crown is wider than long, the lingual face of the crown is nearly straight without a wide lip, the labial face is concave, and the labial part of the crown has a short ridge at the summit which divides into two branches, each joining the lateral angles. *R. sudhakari* is distinguished from *R. harrisae* in which the male teeth are highly cuspidate, base of the crown is highly inflated, a transverse cutting ridge is absent but a labial cutting ridge is present, the cuspid is more lingually inclined and the teeth are larger in size. *R. sudhakari* does not show any affinities to *R. gentili* in which the lateral teeth are pyramidal in shape, lingual extension of the uvula does not reach the indentation of the root lobes, a small ridge is present on the lingual face and often a similar one on the labial face, the male teeth have elongated, lingually inclined cuspids with a distinct collar at the base, and the root is expanded. outflanking the crown basally and with two laterally diverging root lobes.

R. sudhakari exhibits the following differences from *R. cecilae*, *R. heinzelini*, *R. terhangensis*, and *R. casieri*: in *R. cecilae*, the cuspid is lanceolate in outline, acute and lingually inclined, root lobes are subquandrangular and outflank the crown on the symphyseal and commissural sides. Similarly, *R. heinzelini* has a tetragonal crown, whose labial face is flat and diamond-shaped, and a root completely masked by the crown in projection. *R. terhangensis* is represented by male teeth with very elongated cuspids bent lingually, a circular or elliptical crown base, laterally expanded root lobes, and a labially wide root canal. *R. casieri* has a massive, flattened crown, a feebly curved labial face, a high and robust root not too developed lingually and root lobes that outflank the crown from symphyseal and commissural sides.

It is clear from the above comparison that the Indian teeth are morphologically distinct from the known species of *Raja* and, therefore, justify their inclusion in a new species.

Rajiforme indet.

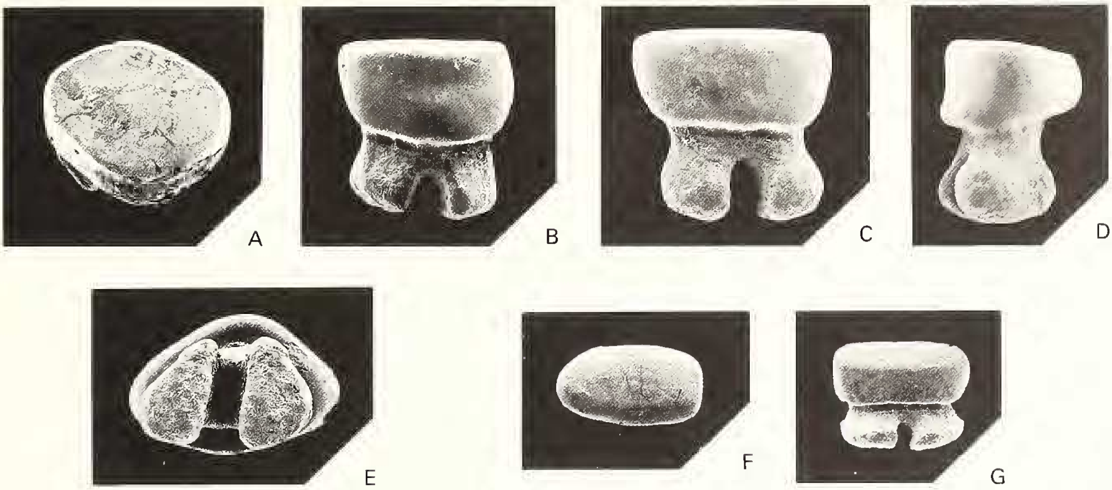
Text-fig. 4

Material. Three teeth, VPL/JU 128–130.

Horizon and locality. Intertrappean beds (green lithic wacke of Text-figure 3) of Asifabad, Andhra Pradesh, India.

Description. As well as the specimens described as *Raja sudhakari*, there are three more teeth in the collection of Asifabad which have a peculiar morphology slightly different from those of the lateral teeth of *R. sudhakari*. Of the three specimens, one is too small (Text-fig. 4F–G) and the other two are large for lateral teeth (Text-fig. 4A–E). In these teeth, the crown is wider than long. The larger specimen (Text-fig. 4C–E) has an ovoidal crown with flat occlusal surface, and is devoid of cuspid; labial and lingual faces of the crown are equally developed and the margins are almost vertical. The root is very large for a lateral tooth and is divided by a groove into two subtriangular or crescentic lobes. The labial margin of the crown is convex and projects medially over the root. The smaller tooth has an elliptical crown which is flat occlusally. The labial and lingual faces are equally developed. The labial face of the crown does not overhang the root like a roof as in the lateral teeth described before. The root is equally well developed, slightly outflanks the crown lingually, and is less wide than the crown. It is divided into a large triangular lobe and a smaller crescentic lobe by a wide groove.

Discussion. The three teeth are morphologically different from the lateral teeth of *R. sudhakari* sp. nov. and probably belong to a different genus. Since there are only three specimens in our collection, we have avoided creating a new taxon and prefer to place them as Rajiforme indet. until additional material is procured.



TEXT-FIG. 4. Rajiforme indet., Maastrichtian, intertrappean beds of Asifabad. A–B, VPL/JU 128; anterior tooth; occlusal and lingual views. C–E, VPL/JU 129; lateral tooth; lingual, profile and basal views. F–G, VPL/JU 130; very lateral tooth; occlusal and labial views. All figures ×43.

Order MYLIOBATIFORMES Compagno, 1973
Superfamily MYLIOBATOIDEA Compagno, 1973
Family MYLIOBATIDAE Bonaparte, 1838
Genus IGDABATIS Cappetta, 1972

Type species. Igdabatis sigmodon Cappetta, 1972

Igdabatis indicus sp. nov.

Plate 2, figs 1–7; plate 3, figs 1–8

1983 *Igdabatis sigmoides* [*sic*] Cappetta; Jain and Sahni, pp. 68–69, fig. 2A–E; pl. 1, figs 1–4.
1986 *Igdabatis* cf. *sigmodon* Cappetta; Courtillot *et al.*, p. 365, fig. 3.

Material. Six median and 190 lateral teeth.

Horizon and locality. Infratrappean beds (green mudstone of Text-figure 3) of Marepalli and intertrappean beds (green lithic wacke and white lithic arenite of Text-figure 3) of Asifabad, Andhra Pradesh, India.

Holotype. VPL/JU 107; Pl. 2, fig. 1.

Derivation of name. After the country of its origin.

Diagnosis. Median teeth 2 to 3·5 times wider than long, transversely arcuated with a convex lingual border and a concave labial border, and acute lateral angles. Sigmoidal contour of the tooth is not a characteristic feature. Crown surface with rugose and pitted ornamentation. Middle part of the crown higher than the lateral ends, hexagonal occlusal outline with slanting labio-marginal facet. Root in polyaulacorhize with root lobes of variable width. Lateral teeth hexagonal or subtrapezoidal in outline, crown wider than long and rather higher; root less high than crown, and root lobes varying from two to four in number. Extreme lateral teeth elliptical or oval in shape and height of the crown reduced; root projects lingually and is divided into a larger triangular and smaller crescentic lobes.

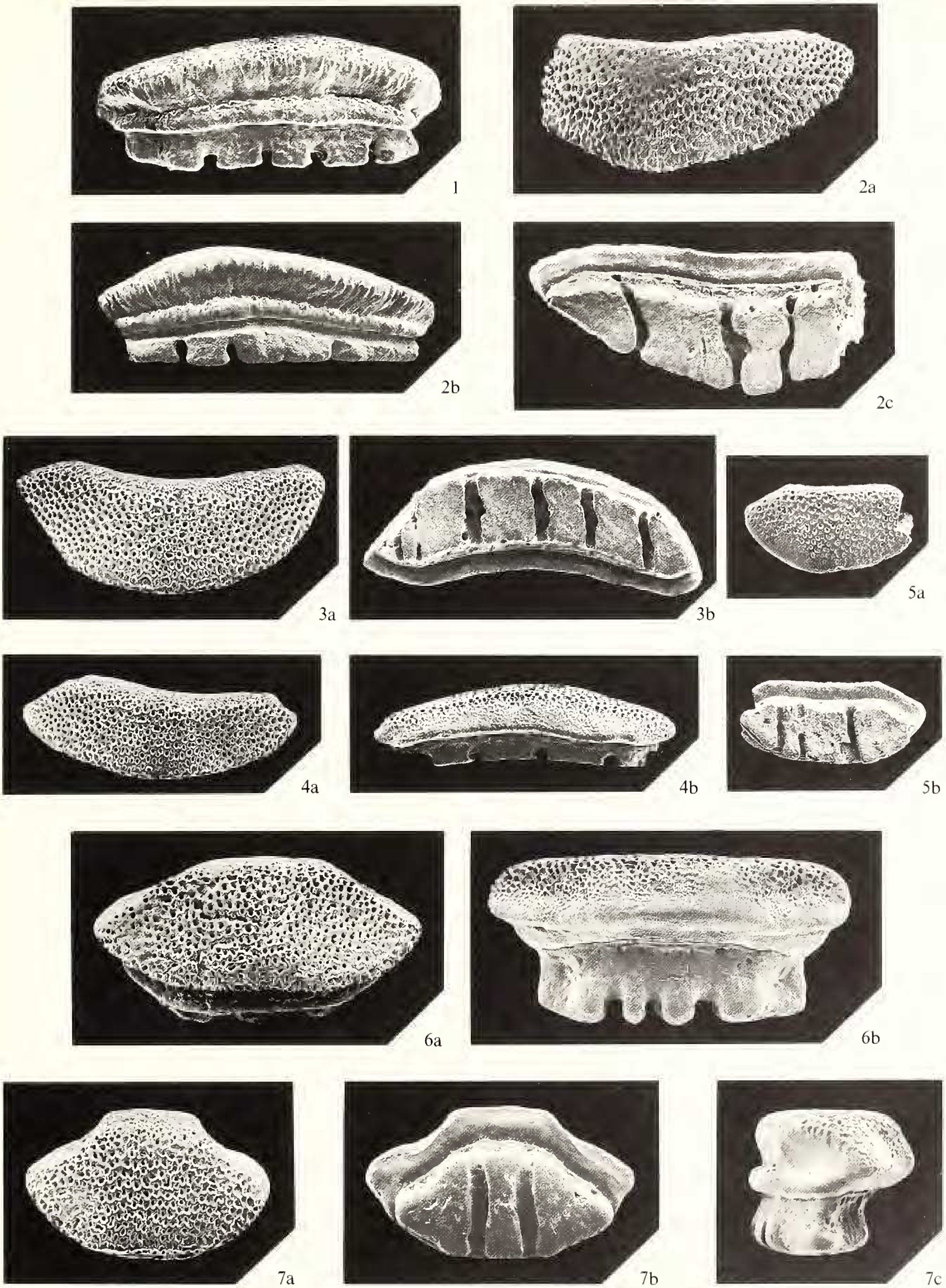
Description. Median teeth are wider than long; the width/length ratio varies from specimen to specimen (2 to 3·5). All the median teeth are transversely arcuated with a concave labial border and a convex lingual (Pl. 2, figs 2–4). The lateral angles of these teeth are oriented labially. The sigmoidal contour of the teeth, a feature characteristic of *Igdabatis sigmodon* Cappetta, 1972 is not distinct except in one specimen (Pl. 2, fig. 3); but even in this specimen it is not profoundly developed. The occlusal surface of the crown is convex and ornamented with polygonal pits. In some small specimens, the surface of the crown is covered with vermiculate or rugose enameloid (Pl. 3, figs 6, 8). The crown is higher than the root and its thickness varies from the middle to the lateral parts. Generally, the middle part of the crown is higher than the lateral ends (Pl. 2, fig. 2*b*). The occlusal surface of the crown is hexagonal in shape, but some of the teeth do not show the lateral facets lingually and form a continuous, convex and arcuate outline. The labial margin of the crown is slightly sloping labially and is ornamented with very fine pits or vertical wrinkles. This is the labial articulating facet for the succeeding tooth. The lingual margin may be smooth or have wrinkles and is separated from the root by a lingual extension of the crown in the form of a rounded ridge. The root in the median teeth shows polyaulacorhize condition being divided into a number of lobes and grooves. In a complete specimen of large size (not figured), there are eight lobes and seven grooves. In a fragmentary tooth with half of the tooth intact, there are five lobes and four grooves, so one may expect about ten lobes and nine grooves in a full specimen. The two lateral lobes are triangular in shape whereas the remaining lobes are rectangular in outline. Width of the lobes and grooves is variable. The grooves bear foramina which may be central in position or may open laterally. Some teeth also bear foramina on the labial face of the root.

Lateral teeth exhibit varied morphology corresponding to their position on the dental plate. Teeth that are close to the median series (Pl. 2, fig. 6) are comparatively larger than those on the extreme lateral ends (Pl. 3, figs 3–5) and have a hexagonal or subtrapezoidal occlusal outline. In some of the worn teeth, the shape becomes fusiform or oval. The crown is wider than long and is ornamented with polygonal pits. As in the median teeth, the labial margin of the crown slopes labially forming an articulating facet for the following tooth row. Similarly, the lingual face of the crown is separated from the root by a rounded ridge-like lingual extension of the crown. Unlike the median teeth, the crown shows an increase in height at its lateral ends (Pl. 3, figs 2*b*, 3*b*, 4*b*). The lateral ends of the labial and lingual faces of the crown meet with an acute angle. The root in the lateral teeth is always less high than the crown. The number of root lobes and grooves probably varies according to their position on the dental plate. Those teeth presumed to be very close to the median series have three or four lobes separated by two or three grooves. Some of the teeth show a central foramen and many irregular foramina opening on the labial face of the root near the junction of crown and root. The extreme lateral lobes are triangular in shape, wider than the medium rectangular lobes. Teeth situated further from the median teeth probably have only two lobes separated by a single groove. The extreme lateral teeth have elliptical or oval crowns (Pl. 3, fig. 5). In these teeth, the height is reduced and the root projects lingually beyond the crown. The root is divided into two unequal lobes; the smaller one is crescentic in outline whereas the larger one is triangular in shape. There are a few teeth in which the crown has the form of a rectangle or parallelogram. In some living genera of batoids, the teeth of the lateral files get compressed transversely and acquire the shape of a rectangle or parallelogram. In addition to the teeth described above, there are ten isolated teeth, smaller in size (0·9 to 1·5 mm in width) with cuspidate crowns at various stages of development. A typical tooth of this kind (Pl. 3, figs 6–8) has a roughly triangular crown. A median transverse crest separates the labial face of the crown from the lingual face.

The part of the crown labial to the central crest is spindle-shaped with a median notch on the labial margin and is centrally depressed. The lingual part is triangular in shape, centrally depressed, and projects lingually over the root in the form of a cuspid. The occlusal surface of the crown exhibits pitted and interconnecting ridge ornamentation. In teeth slightly larger than the above (Pl. 3, fig. 7), the median concavity of the labial margin becomes reduced, the median crest is blunt and broader, the lateral ends of the spindle-shaped labial crown become more rounded, acutely pointed, and the lingually projecting cuspid has a straight linear face.

EXPLANATION OF PLATE 2

Figs 1–7. *Igdabatis indicus* sp. nov. Maastrichtian; infratrappean beds of Marepalli. 1, VPL/JU 107; holotype; median tooth; lingual view, ×9·6. 2, VPL/JU 108; median tooth; *a*, occlusal view; *b*, lingual view; *c*, basal view, ×15·6. 3, VPL/JU 109; median tooth; *a*, occlusal view; *b*, basal view, ×15·6. 4, VPL/JU 110; median tooth; *a*, occlusal view; *b*, labial view, ×15·6. 5, VPL/JU 111; lateral tooth; *a*, occlusal view; *b*, basal view, ×15·6. 6, VPL/JU 112; lateral tooth; *a*, occlusal view; *b*, labial view, ×13·2. 7, VPL/JU 113; lateral tooth; *a*, occlusal view; *b*, basal view; *c*, profile, ×13·2.



PRASAD and CAPPETTA, *Igdabatis*

The root is divided into two triangular lobes by a central groove. The groove bears a central foramen and many irregular pits open also on the labio-lingual distal faces of the root. These teeth with their cuspidate crowns and smaller size are distinct from the median and lateral teeth described above. At first one gets an impression that the cuspidate teeth represent male individuals of the same species. But their small size and morphology of the crown do not favour such a conclusion. It is probable that this type of tooth belonged to young specimens, but absence of a complete dental plate of the genus *Igdabatis* for comparison and their occurrence in association with median and lateral teeth of *Igdabatis indicus* sp. nov. does not permit a definitive conclusion.

Discussion. At generic level, the present specimens exhibit close morphological similarities to *Igdabatis* reported from the Maastrichtian of Niger (Cappetta 1972). The median teeth, as in *Igdabatis*, are transversely arcuate, broader than long, have crowns with variable thickness, are hexagonal in outline, and have roots formed of alternating lobes and grooves maintaining more or less the same height throughout the breadth of the root. This genus has so far been represented by a single species *Igdabatis sigmodon* Cappetta, 1972, the specific name being derived from the sigmoidal contour of the teeth. As well as the present collection, *Igdabatis* has previously been reported from two other localities in peninsular India. One is from the Lameta sediments of Pisdura (Jain and Sahni 1983) and the other is from coeval beds at Jabalpur (Courtillot *et al.* 1986). The tooth from Jabalpur is fragmentary (0·4 mm in width) whereas the teeth from Pisdura are complete (13·2 mm in width). In the present collection also there is a fragmentary tooth which approaches the size of the teeth from Jabalpur and Pisdura (estimated width approximately 16 mm). In contrast to the Indian specimens, median and lateral teeth of *Igdabatis sigmodon* reach a maximum size of 26 mm and 10 mm in width respectively. On the other hand, the lateral teeth from Indian localities do not exceed 5 mm in width. Other than the differences in size, the Indian specimens also differ from the African species in the morphology of median and lateral teeth. The median teeth, though transversely arcuate, do not show the strong sigmoidal curvature characteristic of *I. sigmodon* or lack any such curvature. In most of the median teeth described in the present paper, the lateral angles point labially.

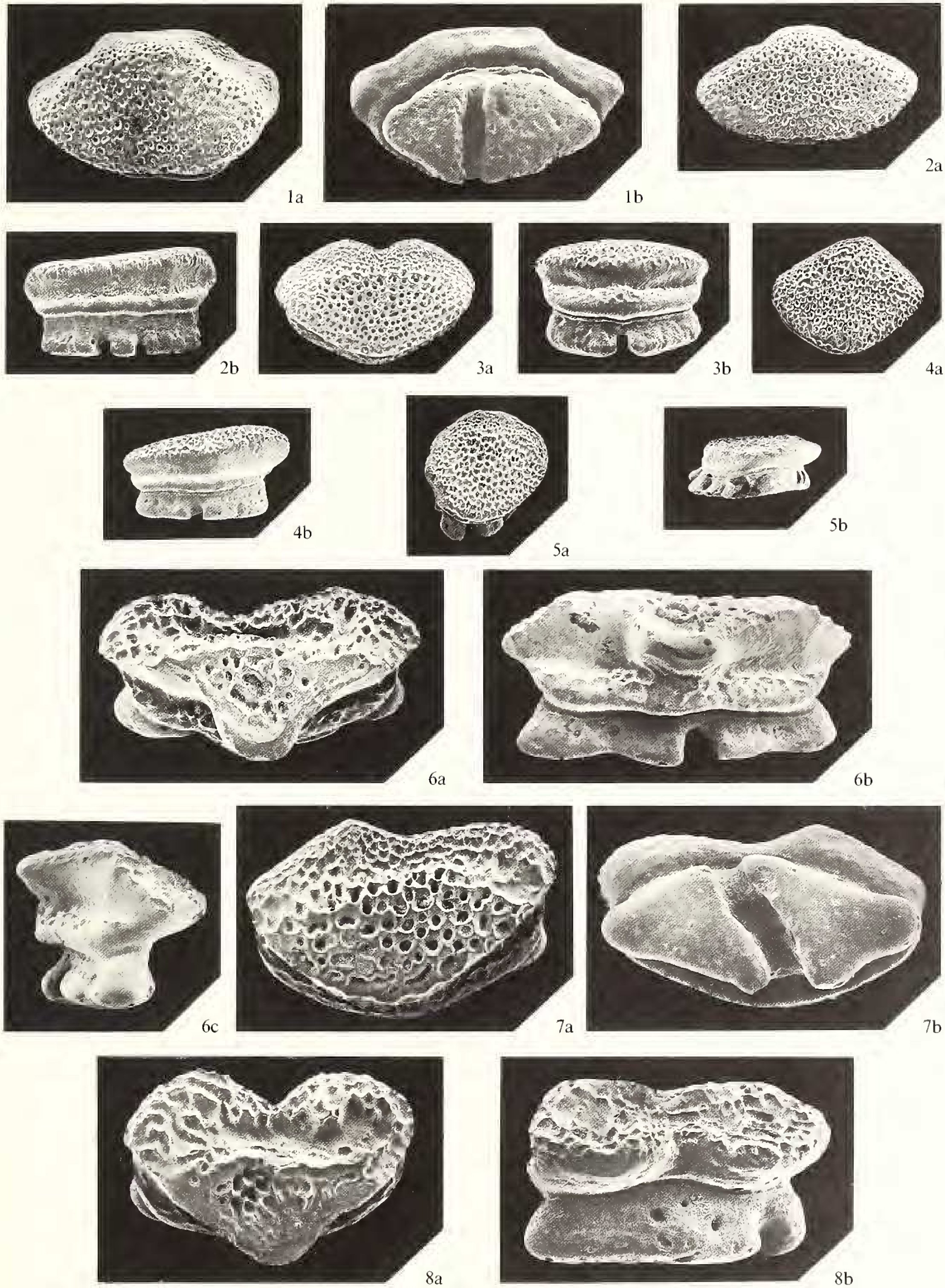
The contour of the median teeth is suggestive of the presence of more than one series of teeth (probably two series) in the middle of the dental plate. Similarly, lateral teeth do not show thickening of the crown at places as in *I. sigmodon* and, therefore, lack asymmetric crowns. Lateral teeth from Asifabad and Marepalli also exhibit widely varying morphology in comparison to those of *I. sigmodon*. Moreover, in *I. sigmodon*, the lingual bulge differentiates a sort of uvula above each root groove, a morphological feature that is not observed in *I. indicus*.

On the basis of the differences in size and morphology between the median and lateral teeth and those of *I. sigmodon*, the Indian teeth are assigned to a new species. Jain and Sahni (1983) described a lateral tooth as *Rhinoptera* sp. Since the morphology of the tooth is similar to that of lateral teeth from Asifabad and Marepalli, its transfer to *I. indicus* is suggested here. Lateral teeth with a morphology resembling those of *I. indicus* have also been reported from the Lameta beds of Jabalpur (Tripathi 1986), intertrappean beds of Nagpur (Rana 1984), Gurmatkal (Srinivasan, personal communication) and Naskal. As discussed earlier, lateral teeth from Nagpur were erroneously assigned to different species of *Dasyatis* and *Rhinoptera*.

EXPLANATION OF PLATE 3

Figs 1–8. *Igdabatis indicus* sp. nov. Maastrichtian; infratrappean beds of Marepalli. 1, VPL/JU 114; lateral tooth; *a*, occlusal view; *b*, basal view, × 13·2. 2, VPL/JU 115; lateral tooth; *a*, occlusal view; *b*, lingual view, × 13·2. 3, VPL/JU 116; lateral tooth; *a*, occlusal view; *b*, lingual view, × 13·2. 4, VPL/JU 117; very lateral tooth; *a*, occlusal view; *b*, lingual view, × 13·2. 5, VPL/JU 118; very lateral tooth; *a*, occlusal view; *b*, profile, × 13·2. 6, VPL/JU 119; tooth of a very young specimen; *a*, occlusal view; *b*, lingual view; *c*, profile, × 36. 7, VPL/JU 120; tooth of a very young specimen; *a*, occlusal view; *b*, basal views, × 36. 8, VPL/JU 121; tooth of a very young specimen; *a*, occlusal views; *b*, labial view, × 36.

PLATE 3



PRASAD and CAPPETTA, *Igdabatis*

Family RHOMBODONTIDAE Cappetta, 1987
Genus RHOMBODUS Dames, 1881

Type species. Rhombodus binkhorsti Dames, 1881.

Rhombodus sp. 1

Plate 4, figs 1–2

Material. Isolated lateral teeth.

Horizon and locality. Infratrappean beds of Marepalli and intertrappean beds of Asifabad, Andhra Pradesh, India.

Description. The teeth are elongated labio-lingually and hence, the length of the crown is much greater than the width. In occlusal view, the crown is in the form of a rectangle or parallelogram. The oral surface, strongly convex transversely and labio-lingually, is ornamented with interconnecting ridges and pits oriented labio-lingually (Pl. 4, fig. 1). Labially and laterally, the crown bears articulating facets. The root is much lower than the crown (Pl. 4, fig. 2), elongated labio-lingually, and divided into two elongated lobes by a wide central groove. One of the teeth from Marepalli (not figured), is subrectangular in outline, smaller than the specimens from Asifabad; the crown, ornamented with pits, is occlusally convex; the root is also rectangular in shape and is divided into two roughly triangular lobes by a deep obliquely oriented groove. At the bottom of the groove, four distinct foramina are visible. Similar foramina are also found on the labial face of the root below the crown.

Discussion. From their general morphology, these teeth correspond to lateral or peripheral lateral elements of the dentition. Because of their size and morphology, they are very different from the teeth of *Rhombodus* sp. 2 and represent a distinct species; but because of the scarcity of material, it is difficult to give a more precise species assignment.

Rhombodus sp. 2

Plate 4, figs 3–6

Material. Nine isolated cuspidate teeth.

Horizon and locality. Intertrappean beds of Asifabad, Andhra Pradesh, India.

Description. The crown in these teeth is roughly rhombic in form, projected lingually with a sharp lingual margin practically cuspidate. The occlusal surface is convex and ornamented with polygonal pits and interconnecting ridges but can be practically flat and smooth because of functional wear (Pl. 4, fig. 4*b*). The crown is higher than the root and lingually the cuspid is connected to the lower limit of the crown by a sharp ridge. The articulating facets on either side of this ridge are deep. Lingual extension of the crown at the junction of crown and root is in the form of a rounded bulge of U-shape. The labial margin of the crown is ornamented with vertical wrinkles. The root has a roughly rhombic outline and is divided by a deep and wide groove oriented obliquely. In some cases (Pl. 4, fig 4), the groove is not fully developed.

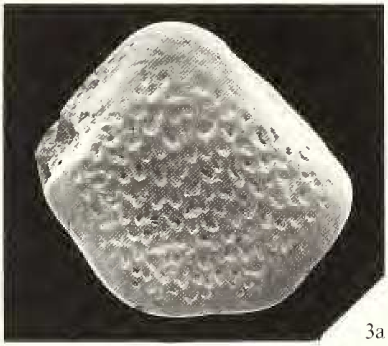
EXPLANATION OF PLATE 4

Figs 1–2. *Rhombodus* sp. 1. Maastrichtian; intertrappean beds of Asifabad. 1, VPL/JU 122; lateral tooth; occlusal view. 2, VPL/JU 123; lateral tooth; profile, × 12.

Figs 3–6. *Rhombodus* sp. 2. Maastrichtian; intertrappean beds of Asifabad. 3, VPL/JU 124; lateral tooth; *a*, occlusal view; *b*, lingual view. 4, VPL/JU 125; lateral tooth; *a*, lingual view; *b*, occlusal view. 5, VPL/JU 126; very lateral tooth; *a*, lingual view; *b*, occlusal view. 6, VPL/JU 127; tooth of the symphyseal region; *a*, labial view; *b*, occlusal view, × 14·4.


1

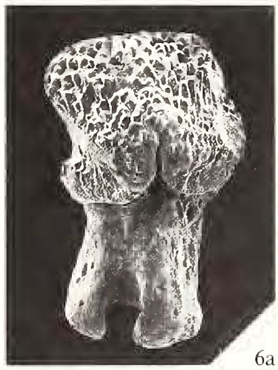

2


3a

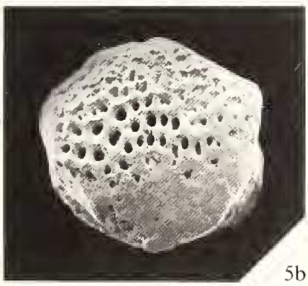

3b

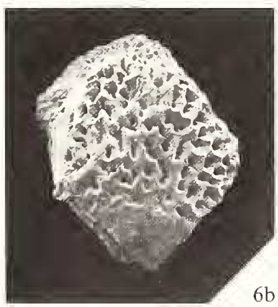

4a


4b


6a


5a


5b


6b

PRASAD and CAPPETTA, *Rhombodus*

One of these cuspidate teeth (Pl. 4, fig. 6) has a pointed lingual cuspid and a convex labial margin with a medium notch. The occlusal surface of the crown is a mosaic of interconnected ridges and pits. The crown is nearly twice as high as the root. The lingual bulge is smooth, broad and has a U-shape. The labial margin of the crown overhangs the root to a great extent. The root is compressed labio-lingually and, hence, elongated width-wise. It is divided into two roughly triangular lobes by a deep groove oriented labio-lingually. No foramina are visible on the bottom of the groove. This tooth is very small (1·4 mm in width).

Discussion. The teeth described here as *Rhombodus* sp. 2 are much smaller than all the known species of *Rhombodus* previously described. In comparison to Moroccan species, which show a trend towards increase in size from Middle Maastrichtian to Late Maastrichtian (nearly 20 mm), the Indian forms are only 4 mm in width. The median teeth are few in number, worn, and their morphology does not compare well with known species of *Rhombodus* such as *R. binkhorsti*, *R. meridionalis*, *R. bondoni*, *R. laevis*, and *R. microdon*. Furthermore, the lateral teeth are larger than, or nearly equal to, the median teeth in size, which is not the case in the dental plates of living batoids. Therefore, the affinity of these teeth is in doubt. Cuspidate teeth further complicate the problem because no cuspidate teeth are known in rhombodontids except in some teeth of *R. microdon*. Absence of a living representative or distantly related form does not allow any comparison with a recent dentition. Teeth of *Rhombodus* have a grinding-type dentition (Cappetta 1987); animals with this type of dentition generally lack cuspidate teeth. Nevertheless, the high, rhombic crown, robust root, and wrinkled crown faces favour their inclusion in *Rhombodus*.

AGE OF THE SEDIMENTS

As discussed before, the age of the intertrappean beds has been the subject of speculation since 1860. Initially, many workers, influenced by the Rev. S. Hislop, the well-known British palaeontologist, and the Indian palaeobotanist Birbal Sahni, favoured a Tertiary (Early Eocene) age for the intertrappean beds. Suggests to the contrary (Cretaceous age) were few in number and were overwhelmed by the flood of reports on intertrappean plant fossils. A few had even proposed an Early Oligocene age for these beds (Shivarudrappa 1978). However, the systematic work carried out by us in recent years has revealed the widespread occurrence of microvertebrate remains along with molluscs, ostracodes, and charophytes in the infra- and intertrappean beds all along the eastern, western, southern, and southeastern margins of Deccan Traps. It is now well established that the fauna and flora from the infra- and intertrappean sedimentary sequences are more or less similar and contain dinosaurs, mammals, pollens and spores which unequivocally favour a Late Cretaceous age (Sahni *et al.* 1986, 1987; Prasad and Sahni 1988; Prasad 1989). The batoid fish fauna described here also lends support for the Late Cretaceous age. The genus *Igdabatis* is restricted to the Maastrichtian sediments of Niger and has not been reported from any other country, except India. In India, this genus occurs in the Lameta sediments of Jabalpur and Pisdura which have been dated as Maastrichtian on the basis of dinosaurs (Huene and Matley 1933; Tripathi 1986) and radiometric studies (Courtillot *et al.* 1988). Similarly, *Igdabatis* was found in association with limb bones and egg shell fragments of sauropod dinosaurs and dental remains of theropod dinosaurs at Asifabad. Therefore, a Late Cretaceous age of the upper range of this genus seems to be an acceptable limit. Likewise, *Rhombodus* is known so far from Cretaceous rocks of Europe, North America and Africa and is considered to have become extinct by the end of that period (Cappetta 1987). *Raja* is not significant biostratigraphically as it ranges from the Cretaceous to the present, but its association with *Rhombodus*, *Igdabatis*, and dinosaurs implies a similar age for the Indian species. It is important to emphasize that isolated teeth of the genus *Raja* are here reported for the first time in Cretaceous deposits. This palaeontological evidence is in agreement with the recent palaeomagnetic and radiometric investigations which had given compressed dates for Deccan Volcanism i.e. 1 to 3 Ma. duration for the volcanic activity across the Cretaceous–Tertiary boundary (Courtillot *et al.* 1986, 1988; Venkatesan *et al.* 1986; Duncan and Pyle 1988).

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